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THE CAUSE OF COLOR IN ROSE QUARTZ (CONCLUDED)

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VI. THE ABSORPTION SPECTRUM OF ROSE QUARTZ

The absorption of light by rose quartz is slight, as might be expected, because of the small amount of pigment present. Wherry,¹ using a microspectroscope, found no absorption for this mineral beyond a shortening of both ends of the visible spectrum. But using a strong arc as the source of light, concentrating the light by a lens, and passing it through sections of rose quartz the writer was able to observe some selective absorption. The results are given in Table V.

TABLE V. THE ABSORPTION OF LIGHT BY ROSE QUARTZ

Spec. no.	Color class	Path of light	Thickness of section	Type of surfaces	Lower limit of transmission	Region of slight absorption	Upper limit of transmission
12a	ii	Transmitted	1.0 cm.	Ground	$0.43 + \mu$	$0.47 - 0.51 \mu$	$0.72 - \mu$
12a	ii	Transmitted	2.1	Unground	.43 +	.47 - .52	.72 -
20	v	Transmitted	1.7	Ground	.43 +	.47 - .51	.71 -
20	v	Reflected	1.7	Ground	.43 +	.47 - .51	.71 -
14	vii	Transmitted	3.7	Unground	.43 +	.47 - .52	.72 -
11	viii	Transmitted	0.9	Ground	.41 +	none	.76 -
10	ix	Transmitted	3.2	Unground	.43 +	.47 - 51	.72 -

In all cases there was some shortening of the visible spectrum, and in all but one section, the thinnest one employed and of a pale color, there was observed a region of slight absorption from $0.47-0.52\mu$, in the blue and blue green.

This result, while in itself alone not conclusive, is confirmative of the evidence of the analyses that the color is due to manganese. It excludes from consideration several other metals, and agrees with the spectrum of Mn''' compounds. From the character of the absorption Cr, Nd, Co,² and colloidal gold, the only metal

¹ Edgar T. Wherry. *Smithsonian Misc. Coll.*, **65**, No. 5, (1915).

² While Co solutions absorb in the blue and green, with a maximum at 0.51μ , they almost always have other absorption bands not shown by rose quartz.

whose colloidal solutions approximate the color of rose quartz,³ would be eliminated.

Of the manganese compounds, permanganates and manganates are excluded because of their instability and non-occurrence in nature, as well as their unfavorable absorption spectrum. Mn^{IV} ($MnCl_4$) solutions transmit only in the orange and red.⁴ Mn^{II} compounds are extremely weak pigments and need not be considered. Rhodochrosite and rhodonite, with 62 and 54% MnO , respectively, are not as deep a pink as many of the rose quartz specimens, which contain less than 1/50,000th as much MnO . Many chemists consider that the Mn^{II} salts owe their color to traces of a compound of Mn in a higher state of valence.

Violet or pink manganese glasses which have been shown by Scholes⁵ to be colored by a Mn^{III} compound, have an absorption spectrum very similar to that of rose quartz. They absorb in the yellow, green, and blue, with a maximum at about 0.49μ . The greater width of the band in these glasses may well be due to their higher Mn content. The maximum absorption is in exactly the same position in the rose quartz (0.49 - 0.495μ). Furthermore, the absorption of Mn^{III} compounds in solutions, as described by Jaeschke and Meyer,⁶ is similar to that of rose quartz. The absorption varies with the acid radicle, that of $MnPO_4$ being the nearest to that in rose quartz. A $MnPO_4$ solution, which contained 0.56% MnO , in a thickness of 1.0 cm. absorbed light from 0.46 to 0.58μ ; one with 0.011% in a thickness of 20cm. absorbed from the ultraviolet up to 0.51μ . Therefore the absorption of rose quartz likewise points to coloring by a compound of manganese, probably of Mn^{III} .

VII. THE DICHROISM OF ROSE QUARTZ

The clear transparent specimens of rose quartz, when examined with the dichroscope, show distinct dichroism. They evidently

³ In *Koll. Z.*, 4, 188, (1909), C. Doelter describes a successful experiment in producing a rose quartz colored by colloidal gold. At a temperature of 900° - 1000° , he passed an electric current through a gilded plate of quartz, cut perpendicular to *c*. Enough colloidal gold was carried into the mineral to color it rose. But he remarks that he should hardly attribute the color of rose quartz in general to colloidal gold.

⁴ W. Jaeschke and J. Meyer. *Z. physik. Chem.*, 88, 281-9, (1913).

⁵ S. R. Scholes. *J. Ind. Eng. Chem.*, 7, 1037, (1915).

⁶ *Op. cit.*

contain large areas in which a crystallographic orientation prevails. The thickness necessary for distinct dichroism to be noted is about 10 cm. in the palest specimens, and only 1 cm. in the more deeply colored ones. In one direction the color is a pronounced pink, in the other almost colorless, with a slight yellowish tinge. When both of the spots seen through the dichroscope are of the same color, they are pink, which indicates the color transmitted by light passing through the specimen in a direction parallel to the vertical axis. The absorption, then, is ω (pink) $>$ ϵ (nearly colorless). This was verified on a thick section of the deepest colored specimen (30), so cut by trial that its faces were parallel to and perpendicular to the optic axis.

The character of the dichroism is another bit of evidence that rose quartz is colored by a Mn''' compound. It is exactly the same as that observed in other pink minerals known to contain Mn''' in appreciable quantities, to which they owe their color. The following table presents the pleochroism of these minerals. In all of them there are two principal colors: rose to violet, and colorless to yellow.

TABLE VI. PLEOCHROISM OF MINERALS COLORED BY Mn''' COMPOUNDS

Mineral	Approx. % Mn_2O_3	Pleochroism
Rose quartz*	0.000x	Pink (ω). Nearly colorless, yellowish tinge (ϵ)
Pink beryl*	0.0x	Pink (ϵ). Colorless (ω)
Kunzite*	0.1	Amethystine to pink (X and Y). Colorless (Z)
Rubellite	0.x-2	Pink (ω). Nearly colorless (ϵ)
Thulite	0.x	Rose (X and Y). Yellow (Z)
Pink andalusite	0.x-7	Rose red (X). Colorless or very pale yellow (Y,Z)
Piedmontite	6-19	Amethyst violet (Y). Bright red (Z). Lemon to orange yellow (X)

* In thick section

VIII. THE LOSS OF COLOR ON HEATING

The color of rose quartz is known to be unstable at a moderate temperature. The results of tests made by Dr. Lind and the writer show that the color disappears when a temperature of about 575°C. (in air) is reached, although there was found no relation between the loss of color and the inversion of α to β quartz, which occurs near the same temperature. The close agreement of

the temperatures is apparently only a coincidence. Hermann⁷ and Simon⁸ have investigated the effects on color caused by heating minerals in various gases. However their work on quartz was chiefly with other varieties than rose quartz.

The writer subjected a number of specimens to four heats at temperatures from 160° to 400°, as follows: (1) 16 specimens were heated to 160°-170° for a continuous period of 81 hrs. (2) 10 specimens were heated to $265 \pm 10^\circ$ for 6 1/2 hrs., in 3 periods. (3) 16 specimens to $345 \pm 10^\circ$ for 3 periods totalling 6 hrs. (4) 16 specimens to 400° (approximately) for one period of 3 1/2 hrs. In none of these heat treatments was the color of any of the specimens visibly diminished. The heating was carried on in air.

Dr. Lind then tried similar experiments, in air, at higher temperatures. (Dr. Bardwell tested specimen No. 30.) Table VII gives the data he obtained. The original color of each specimen, and the class to which its color had dropped after each heating, are given.

Dr. Lind came to these conclusions: "The decolorization is certainly a time reaction and I see no evidence from the experiments that there is any sharp change in the rate around the transition temperature of 575°, though the change appears to set in just below or in the neighborhood of this temperature; but the third heating makes it very evident that merely passing the transition temperature does not hasten decolorization any more than would be expected merely from a rise in temperature. There was certainly a tendency of some of the specimens to be decolorized more rapidly than others. This tendency does not appear to depend upon the amount of color originally present. . . . The color reduction seems to be a true one of kind, that is, in no case did the color go off to any other one, but gradually reduced the depth of the rose color."

How do these results agree with the theory that the color of rose quartz is due to a compound of Mn^{'''}? Manganese compounds readily change their state of oxidation under conditions of rising temperature, and the loss of the rose color at or near 575° is certainly not opposed to a coloring by Mn^{'''}, especially since the Mn compound in rose quartz must be in a very finely divided state, and would be therefore likely to be more than usually susceptible

⁷ W. Hermann. *Z. anorg. Chem.*, **60**, 369-404, (1908).

⁸ K. Simon. *Neues Jahrb. Mineral.*, Beil.-Bd. **26**, 249-95, (1908).

TABLE VII. THE DECOLORIZATION OF ROSE QUARTZ BY HEATING IN AIR

1st heating: 2 1/2 hrs. at 530°.

2nd heating: 2 hrs. at 560°-590°.

3rd heating: 3 hrs. at 575-630°.

Color class original	Spec. no.	Result of		
		1st heating	2nd heating	3rd heating
i	30	_____	(ix) ⁹	(xi) ¹⁰
ii	12a	no change	vi	xi
iii	1	"	x	xi
iii	9	"	vi	xi
iv	8	"	vi	xi
v	20	slight reduction	xii	xiii
v	21a	some reduction	xiii	xiv
vi	16	no change	ix	xi
vi	7	"	ix	xii
vi	28	"	xii	xiii
vii	14	_____	_____	xiv
viii	11	no change	xiii	xiv
ix	18	_____	_____	xii
ix	10	_____	_____	xi
ix	17	_____	_____	xiii
ix	13	_____	_____	xii
x	19	_____	_____	xii
x	24	_____	_____	xiii
xi	2	_____	_____	xiv
xii	23	_____	_____	(xiv) ¹¹
xiii	27	_____	_____	xiv
xiii	6	_____	_____	xiv
xiii	21b	_____	_____	xiv
xiii	12b	_____	_____	xiv
xiv	This is the color of class xiii after heating.			

⁹ Result of special heating, 2 hrs. at 600°.¹⁰ Result of special heating, 2 hrs. at 675°.¹¹ Owing to decrepitation in heat 2, this specimen was given a special heating of 19 1/4 hrs. at 600°-590°, with the result noted.

TEMPERATURE RECORDS. Heat No. 1. In at 9.30 A.M., temp. 530°; 10.15, 530°; 11.00, 530°; out at 12.00 M., 538°. Heat No. 2. In at 1.00 P.M., 560°; 1.30, 560°; 2.00, 570°; 2.30, 580°; out at 3.00 P.M., 590°. Heat No. 3. In at 9.00 A.M., 575°; 9.30, 610°; 10.00, 620°; 10.30, 622°; 11.00, 623°; 11.30, 630°; out at 12.00 M., 631°. Special heat for specimen No. 23: In at 2.00 P.M., 600°; 3.00, 600°; 5.00, 600°; 8.00, 600°; out at 9.15 A.M., 590°.

to temperature changes. Either a reduction to MnO or oxidation to MnO_2 , would discharge the color. Whatever the mechanism of the loss of color, it is certainly one that can be undergone by Mn_2O_3 , for the dried silica gel colored by Mn''' , described in part IX of this paper, loses its color on heating even more readily than does the rose quartz. This is probably because the gel is more porous.

It might be added that Bamberger and Grengg¹² state that rose quartz does not suffer any change in color when cooled to -190° .

IX. SIMULATION OF ROSE QUARTZ

Since from several points of view a compound of trivalent Mn is suggested as the pigment of rose quartz, an endeavor was made to reproduce the color synthetically with Mn''' . In a borax fusion, 0.01% MnO produced a color equivalent to that of rose quartz of color class v. Manganese in such fusions is trivalent. Of more significance is the fact that it was possible to duplicate the color by means of a Mn''' compound in silica gel. The gel was prepared by the addition of a phosphoric acid solution to a solution of sodium silicate, "water glass." A Mn''' borate was prepared by fusing Mn in borax. The gel, when firm, was broken up and covered with a solution of the Mn''' borate in phosphoric acid. This was absorbed by the gel, giving it a rose color. By very slow drying at about 70° a glassy hydrated silica, colored by a trivalent Mn compound, was obtained. In composition it differed from rose quartz only in containing more water. Its resemblance to that mineral was practically perfect. Material so prepared, which was of a much deeper color than any of the rose quartz, contained 0.02% MnO . This experiment is a strong indication, in connection with the results previously described in this paper, that it is to a compound of trivalent manganese that rose quartz owes its color.

It was necessary to use 0.01% MnO to reproduce the color of the deepest rose quartz in the laboratory, while in nature, as the analyses indicate, much less suffices. But it was noted that on drying the gel containing Mn''' its color deepened. It is probable that the action of heat and mineralizers in nature is such as to bring out a deeper color, with a given amount of Mn, than was

¹² M. Bamberger and A. Grengg. *Centr. Mineral.*, 65-74, (1921).

possible in the laboratory. This is not surprising, when it is considered that 2.5% Cr_2O_3 is necessary to give artificial ruby the color caused by traces of that element in the natural mineral.

The rose colored silica gels lost their color at a temperature even lower than that at which rose quartz is decolorized. At this temperature the gel structure did not break down, so that the loss of color is not an apparent loss caused by a structural disintegration of the gel, but is due to some change in the Mn compound. Dr. Bardwell, who carried out tests upon three samples of these rose colored gels, reports that a heat treatment of 30 minutes at 200° caused the loss of color in two, while the third retained a slight pink. At 330° a 15 minutes treatment completely decolorized all three, and caused them to become translucent. This establishes the fact that a moderate temperature may cause the loss of colors which are due to the presence of small amounts of compounds of trivalent manganese.

Dr. Bardwell exposed three samples of each of the three gels to β and γ radiations from 230 mg. Ra for 78 days; for each gel some of the original fragments, some of the fragments which had been heated to 200° for 30 minutes, and some which had been heated to 330° for 15 minutes. In no case was any change of color caused by the radiation, although in the same period a specimen of dark rose quartz (No. 30) changed to a very dark smoky color. Either the artificial products do not contain whatever substance is responsible for the production of the smoky color in radiated rose quartz or the difference is one of state.¹³ These experiments indicate conclusively that the radium-induced smoky color has no connection with the rose color, caused by manganese.

X. SUMMARY AND CONCLUSIONS

Since the research here described dealt with a large number of specimens of rose quartz, the results may be generalized to apply to all occurrences of that variety. Rose quartz is always massive, and occurs in association with granitic rocks. Its color can not be due to the action of radioactive substances on white quartz, since

¹³ Dr. Bardwell says in this connection, in a communication: "It seems to me that in terms of our (Lind and Bardwell, *this journal*, 8, 178, 1923) theory of the coloring of stones by radiation that the difference between natural rose quartz and the silica gels is one of state. These silica gels can probably not be considered true solids, and therefore the displacement of electrons by radiation is not permanent, because they are not held in their displaced positions but can return."

it is impossible to reproduce the color on heat decolorized specimens, or to strengthen the color, by means of strong radium preparations. In every case the color so obtained was that of smoky quartz. The analyses show that the color can not be due to compounds of Ti or Fe, or to hydrocarbons. Ti is accounted for by the universally present rutile inclusions, and Fe is derived chiefly from limonite stains. But Mn varies regularly in amount with the depth of color, and there are no inclusions to which it is due. Rose quartz is decolorized in air near $575^{\circ}\text{C}.$, and if formed above that temperature quartz will be white even though it may contain enough manganese to have colored it at a lower temperature. The absorption spectrum agrees with that of Mn''' glasses and solutions. Its pleochroism is exactly like that of other minerals which owe their color to Mn''' . The loss of color on heating is accounted for by a change in the valence of the manganese. Rose quartz was very closely simulated in amorphous hydrated silica, colored by only 0.01% MnO . This silica gel was even more easily decolorized by heat than was the natural rose quartz.

There is, therefore, a strong convergence of different lines of evidence leading to the conclusion that rose quartz owes its color to the presence of trivalent manganese.

THE PROPERTIES OF SCAPOLITE

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The chief constituent molecules of scapolite were first recognized by Tschermak¹ fifty years ago. This made it possible for Lacroix² to show that, in general, the refringence and birefringence increase with increase of calcium. About fifteen years ago Himmelbauer³ investigated the matter in more detail and prepared diagrams showing the relations between variations in composition and in the length of the vertical axis, the specific gravity, the refringence and the birefringence. He assumed rectilinear variations in all cases. Discrepancies were not small in all cases, but were attributed to impurities.

¹ *Sitz. Akad. Wiss. Wien.*, LXXXVIII, I, 1154, (1883).

² *Bull. Soc. Fr. Min.*, XII, 356, (1889).

³ *Sitz. Akad. Wiss. Wien.*, CXIX, I, (1910).

About ten years ago Borgström⁴ laid the foundation for more accurate work by showing that the molecules proposed by Tschermak are not the only ones concerned in the composition of scapolite, and that one of Tschermak's molecules is probably not exactly correct. Recently, Sundius⁵ has shown that two of Borgström's molecules need slight corrections, while Goldschmidt⁶ has emphasized the importance of potassium in scapolite and Shannon⁷ has shown that fluorine may be abundant. Accordingly, the present status of knowledge regarding the composition of scapolite may be summarized as follows; the chief constituents are: $\text{NaCl} \cdot 3\text{NaAlSi}_3\text{O}_8$ and $\text{CaCO}_3 \cdot 3\text{CaAl}_2\text{Si}_2\text{O}_8$.

However, the following molecules are also present, sometimes in important amounts: $\text{NaHCO}_3 \cdot 3\text{NaAlSi}_3\text{O}_8$, $\text{NaHSO}_4 \cdot 3\text{NaAlSi}_3\text{O}_8$, and $\text{CaSO}_4 \cdot \text{CaAl}_2\text{Si}_2\text{O}_8$. $\text{KHCO}_3 \cdot 3\text{NaAlSi}_3\text{O}_8$ is not uncommon in small amounts and in rare cases it is important; K may probably replace part of Na in other molecules, also. Finally, in one case, fluorine seems to replace all other acids (except silicic) in meionite in the molecule $\text{CaF}_2 \cdot 3\text{CaAl}_2\text{Si}_2\text{O}_8$.

This new and more accurate information regarding the constituent molecules of scapolite has apparently stimulated research regarding the exact relations between variation in composition and variations in physical, and especially optical, characters. In the short time since Borgström's paper appeared some eighteen different scapolite crystals have been studied both chemically and optically, and these studies have been of an accuracy such that earlier data, including the results of Himmelbauer, must be rejected as no longer important, except in the historical sense.

A summary of the new data is presented graphically in Fig. 1. Sundius⁸ prepared diagrams of this general character, but he always used the function $\frac{N_o + N_e}{2}$, instead of the indices separately. A more accurate value of the mean index would be derived from $\sqrt[3]{N_o^2 \times N_e}$. The index most easily used in microscopic work is N_o , rather than any mean value; therefore, a diagram

⁴ *Zeit. Kryst.*, LIV, 238, (1915).

⁵ *Bull. Geol. Inst. Upsala*, XV, 1, (1916), also XVI, 96, (1918).

⁶ *Die Kontaktmetamorphose im Kristianagebiet*, 315, (1911).

⁷ *Proc. U. S. Nat. Mus.*, LVIII, 481, (1920).

⁸ *Geol. Kirunagebiets. 4. Vetén. prak. undersök. Lappland, Kirunavaara Aktieb.* 195, (1915); see also his other articles, already cited.

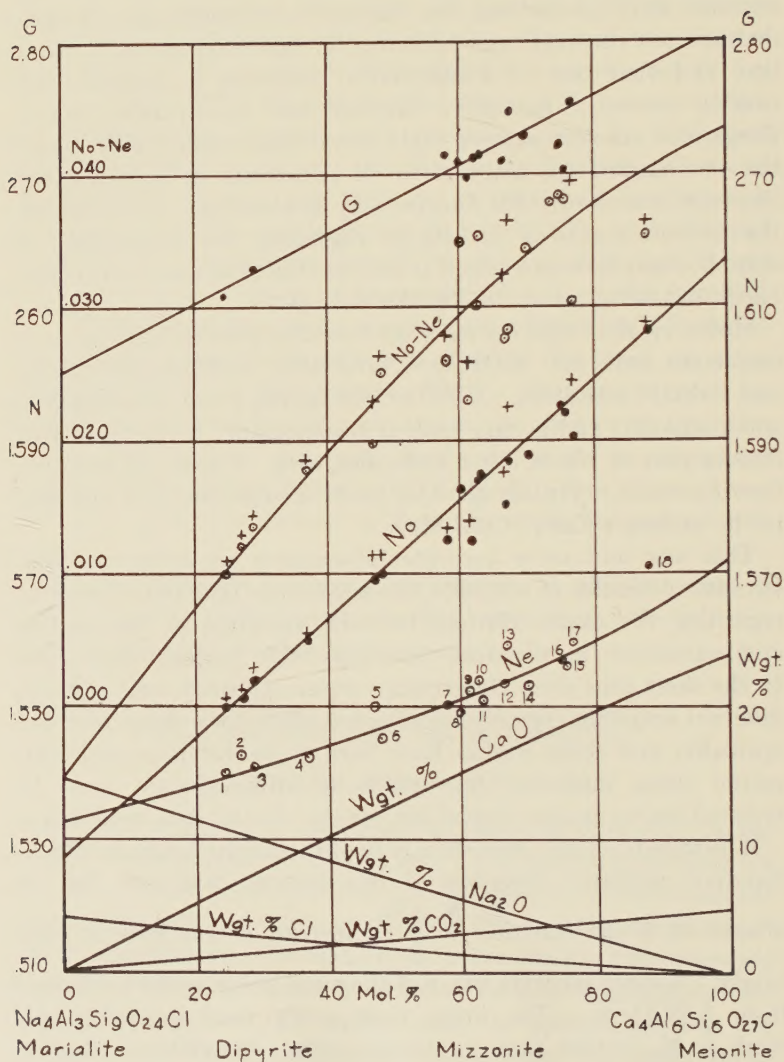


Fig. 1. Relations between composition and physical characters in scapolite. Recorded data indicated by dots and circles; data corrected for other than the chief molecules indicated by crosses—these are above the preceding in all cases.

showing this value separately should be of service. Moreover, the new diagram brings out some unexpected features. After entering all available data, first as given (shown by • and ⊙), and then as corrected (shown by +), so far as possible, to make proper allowance for the presence of other molecules besides those on which the diagram is based, it appears that straight lines are satisfactory to show the variations in specific gravity and in the ordinary index (N_o), but they are not satisfactory for the extraordinary index (N_e) nor for the birefringence. Further, the data indicate that pure marialite would be positive, while a crystal of composition about $\text{Ma}_{90}\text{Me}_{10}$ would be isotropic.

Curves are included in the diagram to show the tenor of Na_2O , CaO , Cl and CO_2 by weight, since some calculation is necessary to obtain them from the molecular composition.

The name wernerite is not included as a subspecies of scapolite since current practice seems to make it synonymous with scapolite as a name for the entire series. The divisions of the series are made at simple decimal ratios.

The diagram is intended to apply to the main series only, namely, $\text{NaCl} \cdot 3\text{NaAlSi}_3\text{O}_8$ to $\text{CaCO}_3 \cdot 3\text{CaAl}_2\text{Si}_2\text{O}_8$. Data are not yet sufficient to permit the preparation of a graph for the other series, but it may be said that the sulphate radical seems to cause a decrease in the birefringence by lowering N_o about .004 for each weight per cent of SO_3 , and it may be inferred from the single carefully studied sample⁹ high in potassa (and water) that these lower the refringence without materially changing the birefringence.

Two comments regarding the relations between composition, space lattices and symmetry in this series seem worthy of record.

First, since chlorine belongs to the oxygen space lattice and CO_3 and SO_4 may take the place of chlorine, the latter groups may substitute (in limited amount) for one oxygen atom without making the crystal unstable, the stability probably depending primarily upon the space lattice of the much larger non-oxygen atoms (Si, Al, Ca and Na).

Second, the radical difference in symmetry between plagioclase and scapolite is perhaps due to the fact that the molecule of the former consists of 5 non-oxygen atoms (or some multiple thereof), while the molecule of scapolite consists of 16 atoms (omitting

⁹ V. M. Goldschmidt: *Vid. Skr. I, Mat. Kl., No. 1*, (1911).

O, Cl, etc.), of which 4 are sodium or calcium, and the others are the nearly equivalent Al and Si atoms.

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11. Gulatal, Norway. N. Sundius: *loc. cit.*, **No. 8**.
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QUARTZ IN METEORIC STONES

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Nearly every detailed analysis of meteoric irons shows traces of silica, which, if reliance can be placed on the examination of the insoluble residues, occurs in the form of minute quartz granules and sometimes distinct crystals. The manner in which these residues have been obtained, it must be confessed, throws a doubt on some of the determinations but the occurrence noted below in the St. Mark's, South African stone, at least insures their possible correctness.

Silica in the form of tridymite (asmanite) it will be remembered constitutes 8.527% of the pallasite of Steinbach, and Berwerth of Vienna has described both quartz and tridymite in the stones of Juvinas, Stannern, Jonzac and Peramho, which he believed to be secondary and due to the breaking down of the pyroxenic

constituent, through the heating incidental to the passage of the stone through our atmosphere.

In his description of the St. Mark's, South African stone, Klein gives the mineral composition as enstatite, olivine, nickel-iron, troilite and "*vielleicht noch Quarz in geringer Menge.*" In examining a thin section cut from a fragment of this stone in the Museum collection I was pleased to more than verify this determination—to be able to write *gewiss* instead of *vielleicht*. Fig. 1, from a photomicrograph of the section shows an aggregate of quartz granules, one (about 0.3 mm in diameter), a crystal cut at right angles to the vertical axis and with good hexagonal outlines. The mineral it will be observed is imbedded in the metal and not in the



Fig. 1. Quartz crystals in St. Mark's meteorite.

silicate portion. I can see no reason for not supposing it to be original rather than secondary, but it should be remarked that the stone is what is known as a black chondrite and presumably owes its color to secondary heating. Whether this heating was due to its passage through our atmosphere or to earlier conditions remains to be shown.

TITANIUM BEARING JEFFERISITE FROM WEST-CLIFFE, CUSTER COUNTY, COLORADO

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Several specimens of jefferisite, and jefferisite bearing rock, recently sent to the Colorado School of Mines for examination and

experimental work, proved to be of considerable interest and the results of the examination are given in this paper.

Jefferisite is grouped with the vermiculites which are considered as decomposition products of the magnesium rich micas, especially biotite and phlogopite, in which the alteration results in a decrease of the magnesium content and a replacement of the alkalis by hydrogen. These alteration products form a series intermediate between the micas and chlorites. F. W. Clarke and E. A. Schneider¹ reached the conclusion that jefferisite was a mixture of hydro-biotite and hydro-clintonite in a ratio of one to one.

Jefferisite was first discovered in commercial quantities by W. B. Thomas in 1913, in the Turrent mining district, 14 miles north of Salida, Colorado. About eight carloads of jefferisite were mined from a twenty inch vein at this locality but the property was abandoned on account of high mining costs. Later another deposit was discovered nine miles from Iola, Gunnison County, Colorado, but this deposit has not yet been sufficiently opened for an examination. The jefferisite described in this article is from an extensive deposit seven miles from Westcliffe, Custer County, Colorado. Several shafts and small open cuts on the property of the Jefferisite Products Company, of Denver, Colorado, all show jefferisite in large quantities.

The jefferisite from the deposit near Westcliffe occurs in plates from four to five inches in diameter, and as small plates in a friable, dark green peridotite consisting of jefferisite, hornblende and small amounts of plagioclase feldspar. It also occurs in a granitic gneiss with abundant white quartz. Although the peridotite appears to be greatly weathered, the individual grains of hornblende and jefferisite, when examined under the microscope, show very little alteration.

The properties of the jefferisite from Westcliffe are: color, dark brown; color by transmitted light, yellowish brown; hardness, 1.5; specific gravity, 2.38; luster, pearly; cleavage, perfect basal; flexible; some plates slightly elastic. Before the blowpipe the jefferisite exfoliates rapidly, the leaves parting to such an extent that the thickness, perpendicular to leaves, after heating is nearly 14 times the original thickness. The force of expansion of the leaves is very great. Upon further heating the leaves fuse to a brownish black slag. In a closed tube the jefferisite exfoliates with

¹ *Z. Kryst.*, 19, 465, (1891).

sufficient force to bend the heated sides of the tube. It gives off considerable water and turns to a silver color. In an open tube the reaction is nearly the same as in a closed tube except that the leaves turn to a gold color. The silver color obtained in the closed tube changes to a gold color when the mineral is reheated in an oxidizing atmosphere. Optically the mineral is biaxial and negative but the optic angle is small. The index of refraction of β and γ is greater than 1.58. Compared with a specimen of jefferisite from Chester County, Pennsylvania, the jefferisite from Westcliffe is darker in color, has a smaller optic angle—about the same as biotite—and shows a higher index of refraction.

A partial analysis of the jefferisite from Westcliffe, made by Albert H. Low, Professor of Chemistry at the Colorado School of Mines, is given below with other analyses for comparison.

	1	2	3	4	5	6
SiO ₂	36.28	37.10	33.35	34.40	34.20	33.03
Al ₂ O ₃	15.92	17.57	17.78	16.63	16.58	17.38
Fe ₂ O ₃	6.35	10.54	7.32	8.00	7.41	7.41
FeO	8.61	1.26	2.11	2.11	1.13	1.44
MgO	15.99	19.65	19.26	19.30	20.41	20.16
H ₂ O	10.98	13.76	19.87	19.03	21.14	20.90
CaO	1.19	0.56	.....	.....	.....	.....
K ₂ O	.....	0.43	.....	.....	.....	.....
TiO ₂	1.74	.....	.....	.....	.....	.....
Undeter- mined	2.94	.....	.....	.....	.....	.....
	100.00	100.87	99.69	99.47	100.87	100.32

1. Westcliffe, Colo. Albert H. Low.
2. West Chester, Penn. G. J. Brush, *Am. Jour. Sci.*, **34**, 133, (1861).
3. " " " A. König, quoted by Genth, *Am. Phil. Soc.*, Sept. 1873.
4. " " " T. M. Chatard, quoted by Genth, *ibid.*
5. " " " F. W. Clarke and E. A. Schneider. *Am. Jour. Sci.*, **42**, 242, (1891). *U. S. G. S. Bull.*, **419**, 291, (1910).
6. " " " A. König, quoted by Genth, *ibid.*

The most noticeable differences between the analyses of the jefferisite from Westcliffe and that from West Chester are the smaller amounts of Fe₂O₃ and MgO, and the titanium content of 1.74 per cent.

The Jefferisite Products Company contemplates the erection of a concentrating plant on the property, from which it will ship the concentrate to its Denver plant for final treatment. The

final treatment consists of grinding; roasting at 1200 degrees in inclined, revolving, internally heated cylinders; air cleaning; pulverizing; and sizing. The uses of the roasted jefferisite are similar to the uses of micas in the manufacture of fire proof roofing, pigments, lubricants and various other products.

A more extensive article on jefferisite has been published as a Circular of Information by the Colorado School of Mines. Those who contributed to the Circular of Information are Victor C. Alderson, President; Albert H. Low, of the Chemistry Department; H. Power Warren, of the Experimental Plant; and W. A. Waldschmidt of the Geology Department.

PROCEEDINGS OF SOCIETIES

NEW YORK MINERALOGICAL CLUB

Regular Monthly Meeting of February 13, 1924

A regular monthly meeting of the New York Mineralogical Club was held in the East Assembly Room of the American Museum of Natural History on the evening of Wednesday, February 13, 1924. The president, Dr. George F. Kunz, presided. There was an attendance of 19 members. The minutes of the last meeting were read and approved. The chairman of the committee on membership reported favorably on the following names submitted at the December meeting:—Albert F. Karlsson, 826 Penfield Street, N. Y. City; A. R. Green, 31-63 Tiffany Place, Brooklyn, N. Y.; and J. F. Schairer, 150 Grove Street, New Haven, Conn. It was moved that the recording secretary cast one ballot for these candidates who were thus declared elected.

Captain Miller discussed the "*Fluorescence of Hyalite from Bedford*," which he found to fluoresce more intensely than the Mexican hyalite. He suggested the presence of autunite as a possible cause. The recording secretary called attention to the proposed meeting of the Section of Geology and Mineralogy of the New York Academy of Sciences in April, and suggested that, inasmuch as Dr. T. A. Jagger Jr. was expected to address this meeting, the Club attend it as a joint session.

Mr. Hoadley moved that Dr. S. G. Gordon of the Philadelphia Academy of Natural Sciences be invited to address the Club at its May meeting. Motion carried. The president read a letter from Madame Curie in reply to a congratulatory telegram sent by the Club on the 35th anniversary of the discovery of radium. Letters were read from Professor Lacroix and Dr. Goldschmidt accepting honorary membership in the Club. The president then introduced Professor J. F. Kemp of Columbia University who delivered an address on "*The Minerals of the Contact Zones*."

Dr. Kemp described the origin of contact zones and dwelt upon the action between an igneous intrusive and a sedimentary rock as a most prolific source of minerals. He discussed the action of a granitic intrusive on sandstones and shales and mentioned the following minerals: sillimanite, andalusite, tourmaline and

biotite. Passing to the minerals resulting from a contact between an intrusive and a limestone he discussed the characteristic lime-alumina and lime-magnesia silicates as formed in the limestone, such as wollastonite, diopside and andradite; and as contributions from the igneous rocks, zoisite, epidote, vesuvianite, wernerite, phlogopite, chondrodite, tourmaline and titanite. Throughout his address the speaker drew freely from his wide experience for interesting and illuminating instances with which he illustrated his points.

At the close of his address a vote of thanks was tendered to Professor Kemp for his highly valuable paper. The meeting adjourned at 10 P. M.

HERBERT P. WHITLOCK, *Recording Secretary*

PHILADELPHIA MINERALOGICAL SOCIETY

Academy of Natural Sciences, March 13, 1924

A stated meeting of the Philadelphia Mineralogical Society was held on the above date with the president, Mr. Vaux, in the chair. Twenty members and five visitors were present. Mr. Trudell proposed the following for active membership: Dr. Thomas Stewart, and Messrs. Edmund H. Cienkowski, George Faust, and James Littel.

Dr. Edward Sampson, of the U. S. Geological Survey, addressed the society on "*The study of ores with the microscope.*" The object of such study is the determination of the relation of minerals to each other, and their identification. It is one of the most recent of mineralogic methods, having been first used by Campbell and Knight in 1906 in the investigation of the Cobalt ores. The principal advances, however, have been made during the past decade, with the rapid improvement in the technique and method of polishing sections. The preparation of sections was described in detail, followed by a description of the microscope used. Many minerals can be readily determined by color distinctions, others only after careful examination of the structure, or the effect produced by a few reagents such as HNO_3 , HCl , FeCl_3 , HgCl_2 and KMnO_4 . The reactions can be hastened by the use of a weak electric current from a battery with terminals of platinum wire and a needle. The needle is placed in contact with the mineral, and the platinum terminal in the solution.

Among the interesting results of this mode of investigation was the following. The well known isometric crystals of cobaltite from Tunaberg showed that they had inverted to an orthorhombic (?) form. From a geologic point of view, much light has been shed on the phenomena of secondary enrichment and the origin of the magmatic sulfide ores. Many mineralogical problems await investigation: the manganese oxides, the amount of rotation of the plane of polarization in anisotropic minerals, and the precise statement of the colors exhibited by minerals in polished section. Much of the technique involved was demonstrated by the speaker, and many beautiful sections were shown illustrating color, structure, pleochroism (covellite), polarization, etc. A rising vote of thanks was extended to Dr. Sampson for his most interesting and instructive communication.

Mr. Trudell described the visit of the following members to Englewood, N. J. to visit the collection of Mr. Charles W. Hoadley, which was followed by a trip to the American Museum: Messrs. Biernbaum, Boyle, Knabe, Gordon, Cienkowski, Oldach, Frankenfield, Arndt, and Trudell. Mr. Boyle described an excursion to

Howellville and Henderson with Messrs. Clay, Cienkowski, Biernbaum, and Oldach. Limonite pseudomorphous after pyrite, and quartz crystals were found.

SAMUEL G. GORDON, *Secretary*

NEW MINERALS: DOUBTFUL SPECIES

CLASS: CARBONATES AND RELATED COMPOUNDS. DIVISION:
ORGANIC COMPOUNDS CONTAINING OXYGEN

"Hoelite"

IVAR OFTEDAL: Minerals from the burning coal seam at Mt. Pyramide, Spitzbergen. *Res. Norske Statsund. Spitsbergenexped.*, 1, no. 3, 9-14, (1922); thru *Min. Abstr.*, 2, 10. [Original not seen.]

CHEMICAL PROPERTIES: Formula $C_{14}H_8O_2$, the compound known in organic chemistry as anthraquinone,
CH CH C CO C CH CH.
CH CH C CO C CH CH

PHYSICAL AND OPTICAL PROPERTIES: Sp. gr. = 1.43. α and β near 1.75, γ near 2.00.

OCCURRENCE: As incrustations around holes from which fumes issue, over the burning coal seam at Mt. Pyramide.

DISCUSSION: More data desired.

E. T. W.

CLASS: PHOSPHATES. DIVISION: Ca : P : F : (CO_2) = 8 : 4 : 2 : 1. (?)

"Kurskite"

V. N. CHIRVINSKII: The phosphorites of Ukraine. *Matter on natural products of Russia, Russ. Acad. Sci.*, No. 30, 52 pp., (1919); thru *Min. Abstr.* 2, 53-54.

NAME: After one locality of the material, *Kursk*, Russia.

CHEMICAL PROPERTIES: Analysis of cryptocrystalline nodules indicates the formula $7CaO.CaF_2.2P_2O_5.CO_2$ or $2Ca_3(PO_4)_2.CaF_2.CaCO_3$, also capable of simplification to $Ca_8(PO_4)_4.(CO_3).F_2$.

PHYSICAL PROPERTIES: Color black; structure nodular to cryptocrystalline, evidently colloidal and metacolloidal.

OCCURRENCE: First observed at Kursk, Russia; now found between Razlety and Vishenki, on the Desna river in the province of Chernigov, Ukraine.

DISCUSSION: Homogeneity and definiteness doubtful. May be an altered spodiosite, $(Ca_4(PO_4)_2F_2)$.

E. T. W.

CLASS: SILICATES. DIVISION: $R' : (R''', R'') : SiO_2 : H_2O = 1 : 4 : 5 : x$

"Soda-glaucanite"

A. F. HALLIMOND: Glaucanite from the greensand near Lewes, Sussex; the constitution of glauconite. *Min. Mag.*, 19, 330-333, (1922); this mineral, p. 333.

NAME: From the composition, a *glauconite* in which part of the potash is replaced by *soda*.

DISCUSSION: In the abstractor's opinion, it is better to use names with chemical prefixes for end-members of isomorphous series, and to apply adjectives to variable intermediate members; in the present instance, the high-soda specimens would be classed as "natriferous glauconite."

E. T. W.

ABSTRACTS

ULLMANNITE FROM ST. ANDREASBERG, HARZ. K. MIELEITNER. *Z. Krist.*, **56**, 105-7, (1921). Ullmannite occurs with calcite, quartz, natrolite, proustite, galenite, and breithauptite in crevices in a shale. Crystals of ullmannite (NiSSb) show the cube, pyritohedron, tetrahedron, and tristetrahedron, which establishes the symmetry (previously in doubt) as tetartohedral. This is an interesting confirmation of the modern theory that the presence of two different negative elements in the pyrite structure should lead to tetartohedrism.

E. T. W.

IRIDOSMINE CRYSTALS FROM RUBY CREEK, ATLIN DISTRICT, B. C. T. L. GLEDHILL. *Univ. Toronto Studies, Geol. Ser.* **12**, 40-42, (1921).

Iridosmine is found in a black sand, and comes from ultra-basic rocks at the head of Ruby Creek. The forms observed were: c , x , a , and new $l(11\bar{2}3)$, $u(11\bar{2}9)$; $a:c = 1 : 1.3823$.

E. F. H.

CALCITE FROM SHANGOINAH ISLAND, NEAR THUNDER CAPE, LAKE SUPERIOR. A. L. PARSONS. *Univ. Toronto Studies* **12**, 51-53, (1921).

The crystals measured were thought to have been formed at the temp. of Lake Superior water in summer, from a solution of CaCO_3 containing CO_2 . The following forms were present; (Goldschmidt symbols) $\bar{2}/2$, 1, 4, 41, $7/4$, $1/4$, $\bar{8}\bar{2}, \bar{8}\bar{4}, \infty 0, \infty$, (new) 48.8/9, 21.10/9.

E. F. H.

A NEW AGATE OCCURRENCE IN THE VOSGES. JULIUS RENCK. *Centr. Mineral.*, 257-9, (1921).

Agates occur near the village of Raon-sur-Plaine.

E. F. H.

A NEW ANDALUSITE OCCURRENCE IN THE FERWALL GROUP (VORARLBERG), AND ITS REGIONAL GEOLOGICAL SIGNIFICANCE. H. P. CORNELIUS. *Centr. Mineral.*, 290-3, (1921).

Peach blossom red andalusite is associated with quartz veins and lenses in schist at the Reutlinger furnace. It seems to be of hydrothermal origin.

E. F. H.

SOME MINERALS FROM FUCHSBAU, FICHTELGEBIRGE. K. MIELEITNER. *Z. Krist.*, **56**, 90-4, (1921).

The first formed minerals in the granite quarry are orthoclase, quartz, albite and zinnwaldite. Upon these are topaz, tourmaline, and apatite. As coatings on all these minerals occur gilbertite, pyrolusite, and limonite. Heated waters circulating thru the fissures have deposited autunite and torbernite and have altered the granite to a red clay which has the composition of kaolinite, and apparently owes its color to a Mn^{+++} compound.

E. T. W.

SOME MINERALS FROM GREGNITZ, FICHTELGEBIRGE. K. MIELEITNER. *Z. Krist.*, **56**, 94-6, (1921).

In addition to minerals such as described in the previous abstract, this locality has yielded good crystals of phenacite apparently formed by alteration of primary beryl.

E. T. W.

THE ECLOGITES OF NORWAY. PENTTI ESKOLA. *Videnskapsselskapets Skrifter*, 1, No. 8, 118 pp., (1921).

This petrologic paper contains much of interest to mineralogists. Clerici's solution is of great value in separating rock constituents for study. It is made by dissolving pure thallium carbonate in a mixture of 85% formic acid and an equivalent amount of malonic acid in a concentrated aqueous solution, and then evaporating until a piece of almandite with sp. gr. 4.0 floats readily. The main part of the paper is concerned with descriptions of the occurrences and origins of Norwegian eclogites, the igneous origin of many of them being conclusively demonstrated. The typical minerals of eclogite, whether of igneous or metamorphic origin, are jadeite-diopside, enstatite, almandite-pyrope, and cyanite. The eclogites have evidently formed under considerable pressure, and on release of pressure some of the minerals have often undergone secondary changes. The jadeite-bearing diopside has broken down into an intimate mixture of sodium-free diopside and plagioclase. There is in general a tendency for the minerals to change toward those characteristic of the amphibolite facies, or even to go farther and approach the minerals of the green-schist facies. This paper represents a very important contribution toward the understanding of the reasons for variation in mineralogy of rocks of given chemical compositions, or as the author terms it, "facies-petrology."

E. T. W.

CONTRIBUTIONS TO THE MINERALOGY OF THE YXSJÖ MINES. N. ZENZÉN. *Geol. För. Förh.*, 44, 539-43, (1921); thru *Chem. Abstr.* 16, 2650.

Massive calcite contained plagioclase crystals. White fluorite, a nearly pure siderite, sp. gr. 3.79, and hisingerite are noted.

E. F. H.

PHENACITE FROM THE GRANITE AT PILBERSDORF AT REICHENBACH IN THE OBERLAUSITZ. M. HENGLEIN. *Centr. Min.*, 1921, 193-195.

Phenacite composed of the two rhombohedrons (1011), (1012), is found in druses in the granite, attached to orthoclase, quartz and penninite but beneath or included in chlorite.

OTTO VON SCHLICHTEN.

THE PRESENCE OF RADIUM AT KATANGA. A. SCHOEP. *Bull. soc. chim. Belgique*, 30, 219-222, (1921).

In the Luiswishi mine a number of radioactive minerals occur. Chrysocolla shows this property owing to intimate admixture of uranium compounds. Gummite occurs as an alteration product of uraninite; it is recognizable by its colloidal properties, and is chemically heterogeneous. A yellow crystalline mineral coating, the gummite, seems to be "uranotile"; analysis gave: UO_3 69.32, SiO_2 14.23, CaO 2.86, P_2O_5 1.10, H_2O 12.28, sum 99.79%. Its mean refractive index is 1.671, and it appears to be in rhombic crystals. These and the other uranium minerals present should be worth investigating for their radium content.

E. T. W.

LINNEITE AT KATANGA. A. SCHOEP. *Bull. soc. chim. Belgique*, 30, 222-223, (1921).

Specimens received from the Luushia mine, between Kambove and Elizabethville, show octahedral crystals indicated by qualitative tests to be linneite.

E. T. W.

ECONOMIC MINERALS OF MADAGASCAR. GEORGE F. KUNZ. *Eng. Mining J.* **111**, 14-6, (1921).

A résumé of the studies of Lacroix and Duparc on the commercially important minerals of Madagascar. Among the numerous minerals found are the following: ampingabeite, autunite, beryl (including gem varieties), betafite, blomstrandite, corundum (no gem varieties), euxenite, fergusonite, garnet (spessartite), graphite, rutile, samarskite, and tourmaline. Graphite, corundum, and ores rich in radium and thorium occur to a great extent in the lateritic clay of the region.

A. S. WILKERSON.

LAUE PHOTOGRAPHS AND STRUCTURE OF ZINCITE. G. AMINOFF. *Z. Krist.*, **56**, 495-505, (1921).

Basal cleavages of zincite from Franklin Furnace were studied by the Laue method. The elementary solid contained two molecules. The intensity distribution in the diagram corresponds to two possible structures, one of which can be selected as agreeing with the Braggs' measurement by another method. The coordinate p of the O atoms is about $5/8$.

PAUL BOONE.

THE CRYSTAL STRUCTURE OF ALABANDITE (MnS). R. W. G. WYCKOFF. *Am. J. Sci.*, **2**, 239-49, (1921).

By a combination of a reflection spectrum from a known crystal face with a powder reflection it is shown that the arrangement of the atoms in alabandite is either that of the "NaCl grouping" or one approaching very closely to it. The mineral is not isomorphous with sphalerite.

E. F. H.

HABIT AND MANNER OF ATTACHMENT OF ICE CRYSTALS. GEORG KALB. *Centr. Min.*, **1921**, 129-134.

Temperature controls the habit of ice crystals. Near 0°C . platy crystals prevail. Lower temperatures favor production of the prismatic habit. The plates rest on an edge, the prisms on one end of the principal axis.

OTTO VON SCHLICHTEN.

THE STRUCTURE OF ALUM. J. J. P. VALENTON. *Z. Krist.*, **56**, 434, (1921).

The growth velocity of different faces on a xl. is connected with the atomic or molecular structure in the direction of each. Measurements on alum show the velocities on (111), (110), and $1\bar{1}0$ to be as 1:3.5:7. The (110) planes contain complete molecules of $\text{KAl}(\text{SO}_4)_2$ and grow fairly slowly. The (100) planes show alternating layers of metal and radical. In the (111) faces the (SO_4) radicals are distorted, causing slow growth.

E. T. W.

A PROOF OF THE TYPES OF SYMMETRY POSSIBLE IN CRYSTAL AXES. P. NIGGLI. *Z. Krist.*, **56**, 531-3, (1921).

A proof that only binary, trigonal, tetragonal, or hexagonal axes of symmetry are possible in crystals.

E. F. H.

ON MONTICELLITE CRYSTALS FROM A STEEL-WORKS MIXER SLAG. A. F. HALLIMOND. *Mineralog. Mag.*, **19**, 193-195 (1921).

The crystals are from $1/2$ to 1 cm in length and from 1 to 2 mm in thickness. Three forms were noted, (010), (110), and (021). Orth., $a:b:c = 0.4382 : 1 : 0.5779$. They are transparent, very pale brown in color, with little or no pleochroism.

Sp. gr. 3.20. $\alpha = 1.663$, $\beta = 1.674$, $\gamma = 1.680$. $2V = 74\frac{1}{2}^\circ$. The chem. analysis reveals 16.5 mol. per cent of olivine present in solid solution, the influence of which is shown in the density, mean refractive index, increased values of $a:b$, $c:b$, and in the larger birefringence.

W. F. H.

THE ALBITE FROM RISCHUNA IN MORPHOLOGIC RELATIONSHIP. BERTA KREBS. *Z. Krist.*, **56**, 386-407, (1921).

Crystals from the Alp Rischuna (Switzerland) had only 0.09% CaO, corresponding to 3.4 mol. % anorthite; sp. gr. $= 2.623 \pm 0.001$; ext. angles on $p = 3.5^\circ$, on $M = 19.3^\circ$. From elaborate crystallographic measurements, and using the heaping-up method for arriving at the probable angles: $a:b:c = 0.6352:1:0.5584$, $\alpha = 94^\circ 14.6'$, $\beta = 116^\circ 35.7'$, $\gamma = 87^\circ 46.0'$. These data must be for essentially pure albite.

E. T. W.

THE CRYSTALLOGRAPHIC AND OPTICAL CONSTANTS OF ANORTHITE FROM VESUVIUS. J. KRATZERT. *Z. Krist.*, **56**, 465-88, (1921).

K. records values different from the accepted ones of Marignac-Descloizeux: $a:b:c = 0.63523:1:0.55048$, $\alpha = 93^\circ 9.5'$, $\beta = 115^\circ 52.6'$, $\gamma = 91^\circ 16.4'$. The aver. cleavage angle PM is $85^\circ 53.3 \pm 2.1'$. The indices are: $\alpha 1.575$, $\beta 1.583$, $\gamma 1.588$. $2V = 102^\circ 28'$. Two analyses averaged: SiO_2 43.34, Al_2O_3 35.31, Fe_2O_3 0.65, CaO 19.93, MgO 0.17, Na_2O 0.39, K_2O 0.36, H_2O 0.21, sum 100.36%. Sp. gr. 2.760 ± 0.003 . $An = 97\%$.

PAUL BOONE.

SOME RECENT ACCESSIONS TO THE MINERAL COLLECTIONS OF THE U. S. NATIONAL MUSEUM. WILLIAM F. FOSHAG. *Proc. U. S. Nat. Museum*, **58**, 303-5, (1921).

Among the minerals mentioned are:—cinnabar xls. and arsenolite, Hunan, China; large scheelite xls., Ryudo, Korea; large clear danburite xl., Obira, Japan; wiluite xls. and a tristetrahedron of achtaragdite, eastern Siberia; zincite xls., friedelinite, and xld. leucophoenicite, Franklin, N. J.

E. F. H.

RECENT ACCESSIONS IN THE DIVISION OF APPLIED GEOLOGY. EARL V. SHANNON. *Proc. U. S. Nat. Museum*, **58**, 323-6, (1921).

Unusual specimens of ores of W, Mo, V, Cr, and Ti; and of salt minerals, are described.

E. F. H.

BIOGRAPHICAL NOTICES OF MINERALOGISTS RECENTLY DECEASED; WITH AN INDEX TO THOSE PREVIOUSLY PUBLISHED IN THIS MAGAZINE. L. J. SPENCER. *Mineral. Mag.*, **19**, 240-262, (1921).

Short biographical sketches of the lives of 44 recently deceased mineralogists. This is followed by a general index containing 275 entries.

W. F. H.

THE MINERAL ALLACTITE. G. AMINOFF. *Geol. För. Förh.*, **43**, 24-52, (1921).

A detailed study of numerous crystals from Långban shows that the forms have the simplest indices when the crystals are so oriented that $a:b:c = 0.8206:1:0.4508$, $\beta = 95^\circ 37'$. Four new forms are noted: (120), (301), ($\bar{2}11$), and (011). For Na, $\alpha = 1.75 \pm$, $\beta = 1.779$, $\gamma = 1.78 \pm$. Three types of paragenesis can be recognized.

E. T. W.